Interreg CENTRAL EUROPE
Co-funded by the European Union

BIM4CE

# BUSINESS PLAN

Bridge monitoring using real-time data and digital twins for Central Europe

04 2026

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# LIST OF ABBREVIATIONS

| ABBREVIATION | DEFINITION |
| --- | --- |
| AI | Artificial Intelligence |
| API | Application Programming Interface |
| BIM | Building Information Modelling |
| BMS | Bridge Monitoring System |
| BoM | Bill of Materials |
| BOT | Build-Operate-Transfer |
| CAGR | Compound Annual Growth Rate |
| CSV | Comma-Separated Values |
| DAQ | Data Acquisition |
| DT | Digital Twin |
| ERP | Enterprise Resource Planning |
| ESG | Environmental, Social and Governance |
| EU | European Union |
| GDPR | General Data Protection Regulation |
| IoT | Internet of Things |
| IFC | Industry Foundation Classes |
| ISO | International Organization for Standardization |
| KPI | Key Performance Indicator |
| LiDAR | Light Detection and Ranging |
| MEMS | Micro-Eletric-Mechanical Systems |
| ML | Machine Learning |
| OIML | International Organization of Legal Metrology |
| PET | Polyethylene Terephthalate |
| PPP | Public-Private Partnership |
| ROI | Return on Investment |
| SaaS | Software as a Service |
| SHM | Structural Health Monitoring |
| SiWIM | Slovenian WIM System by Cestel |
| SMT | Surface-Mount Technology |
| TCO | Total Cost of Ownership |

| ABBREVIATION | DEFINITION |
|---|---|
| **WIM** | Weigh-In-Motion |
| **XML** | Extensible Markup Language |

# 1. BASIC INFORMATION ABOUT THE PROJECT/PRODUCT

Project Title: BIM4CE – Bridge Monitoring using Real-Time Data and Digital Twins for Central Europe
Project ID: CE0100439
Programme: Interreg CENTRAL EUROPE 2021–2027
Project Duration: 30 March 2023 – 29 March 2026 (3 years)
Project Website: https://www.interreg-central.eu/projects/bim4ce/
Coordinator: Technische Universität Dresden (Germany) – Dr. Ilia Lashkov
E-Mail: ilia.lashkov@tu-dresden.de

**Project Summary**

BIM4CE aims to strengthen innovation capacities in Central Europe by developing and demonstrating an integrated bridge monitoring system based on real-time data acquisition and digital twin technologies. The project introduces a standardized, smart, and cost-efficient method for continuous bridge monitoring that enhances safety, maintenance efficiency, and infrastructure resilience.

Through the combination of sensor technologies, data connectivity, and digital modeling, BIM4CE creates a digital twin for selected pilot bridges. The digital twin serves as a dynamic digital representation of physical infrastructure, continuously updated with real-time monitoring data to support predictive maintenance and early detection of structural issues.

**Project Objectives**

- Develop and validate a transnational bridge monitoring framework using sensor data integration and digital twins.
- Demonstrate the effectiveness of new monitoring methods through pilot actions in participating countries (Italy, Germany and Slovenia)
- Increase the cost-efficiency and accessibility of digital twin technology for broader infrastructure use beyond flagship structures.
- Strengthen cross-border cooperation in research, development, and digital innovation in the infrastructure sector.
- Create a strategy and action plan for the large-scale implementation of digital bridge monitoring systems across Central Europe.

**Core Innovation**

The project introduces printed and flexible leakage sensors developed at TU Dresden, enabling low-cost, scalable monitoring solutions. Combined with MEMS-based accelerometers and inclinometers, these systems deliver comprehensive static, dynamic, and environmental data on bridge performance.

Data is processed through a multi-layer digital platform, integrating:

- Hardware architecture (sensor networks, acquisition units, power and communication systems);
- Software architecture (data collection, cloud storage, analytics, and visualization dashboards);
- Automated alert and diagnostic tools for early warning and decision support.

**Pilot Implementation**

The pilot phase includes:

- Selection of suitable digital twin creation methods and measurement systems.
- Design, installation, and testing of monitoring systems on selected bridges.
- Validation of system durability, accuracy, and real-time data transmission performance under varying environmental conditions.

Expected results:

- A comprehensive bridge monitoring model combining real-time data and digital twin technology.
- A replicable and cost-efficient monitoring framework adaptable to different bridge types and regional contexts.
- Increased safety and reliability of bridge infrastructure in Central Europe.
- Strengthened transnational collaboration in digital innovation and infrastructure management.

# 2. PRESENTATION OF THE PARTNERSHIP

The BIM4CE project brings together a strong, interdisciplinary partnership of leading universities, research institutes, engineering companies, and public organizations from several Central European countries. The consortium is designed to combine scientific expertise, technological innovation, and practical infrastructure management experience, ensuring both high-level research results and real-world applicability.

**1. Technische Universität Dresden (TUD), Germany**

TUD serves as the project coordinator and scientific lead, responsible for the development and integration of the digital twin framework and sensor technology. The university's Institute of Civil Engineering provides extensive expertise in structural health monitoring, printed sensors, and digital infrastructure management. TUD also coordinates the testing and validation of novel flexible sensors (pressure, moisture, and temperature) and ensures the scientific integrity of all project outputs.

**2. SINA S.p.A., Italy**

SINA, the engineering company of the ASTM Group, manages a significant portion of Italy's motorway network. It contributes practical experience in bridge management, monitoring implementation, and data-driven maintenance planning. SINA leads the demonstration activities and pilot testing on Italian bridges.

**3. ZAG - Slovenian National Building and Civil Engineering Institute, Slovenia**

ZAG is Slovenia's leading public research institution in the field of civil engineering. Within the project, it focuses on national bridge typologies, structural analysis, and adaptation of the monitoring framework to the Slovenian infrastructure context. ZAG also supports testing and data interpretation for pilot bridges in Slovenia.

**4. CESTEL d.o.o., Slovenia**

CESTEL provides technological and engineering expertise in the design, installation, and maintenance of monitoring systems. The company contributes to the integration of monitoring hardware and communication systems for real-time data acquisition and analysis.

**5. SPd - Schüßler-Plan Digital GmbH, Germany**

SPd is an engineering company specialized in Building Information Modeling (BIM) and infrastructure digitalization. The company contributes to the development of the digital twin model architecture, providing the link between raw monitoring data and its visualization in a digital environment.

**6. FOS S.p.A., Italy**

FOS specializes in IoT technologies, automation, and smart systems. Within BIM4CE, it contributes to the development of data acquisition platforms, ensuring interoperability between sensors, networks, and the digital twin software environment.

**7. CSP Innovazione nelle ICT, Italy**

CSP provides expertise in data management, cloud solutions, and ICT integration. The partner supports the design of the software architecture, including big data processing, analytics, and web-based visualization tools for the monitoring dashboard.

**8.BP Akademija, Slovenia**

As an NGO, the institution focuses on training, knowledge transfer, as well as project-based learning in the fields of business, innovation, and sustainability. Within the BIM4CE project it plays a key role in capacity building and dissemination, organizing workshops and preparing materials aimed at professionals, public authorities and stakeholders. BP Akademija ensures that the technological innovations developed within the project are translated into practical knowledge and long-term competencies.

The strength of the BIM4CE partnership lies in its multidisciplinary and transnational nature, connecting academic research, industrial innovation, and educational expertise. Each partner contributes specific competencies that together form a complete value chain — from sensor development and data collection to data analysis, visualization, and professional training. The consortium's composition ensures that innovative technologies are not only developed and tested but also effectively transferred into practice through knowledge exchange and skill development.

By combining engineering excellence, digital expertise, and strong regional collaboration between Germany, Italy, and Slovenia, the partnership creates a powerful platform for sustainable innovation. This integration of science, technology, and education guarantees that the project's outcomes will have a lasting impact on infrastructure safety, digital transformation, and workforce development across Central Europe.

# 3. DESCRIPTION OF THE PROJECT (INVESTMENT)

## 3.1. FUNDAMENTAL OBJECTIVES OF THE PROJECT

BIM4CE delivers a standardized, affordable, and scalable digital bridge monitoring solution that fuses real-time measurements with digital twins to improve maintenance decisions, safety, and resilience across Central Europe. It is being implemented because many bridges are aging, face higher-than-designed loads, and still rely on manual, costly inspections that create maintenance backlogs and safety risks. The core problem is the lack of a practical EU-wide standard: current systems are bespoke, complex, and expensive, which blocks broad adoption and consistent, data-driven asset management. The project integrates cost-effective sensors (including configurable printed foils), connectivity, analytics, and BIM models, validates them through transnational pilots, and provides clear strategies and action plans for rollout and uptake. The intended change is continuous, actionable monitoring that reduces failures and closures, extends asset life, and strengthens innovation transfer and cooperation among authorities, operators, and industry for EU-wide deployment.

## 3.2. DETAILED DESCRIPTION OF THE PROJECT

The project is organized into three phases—foundations and requirements, development with pilots, and adaptation/upscaling—culminating in a validated, standardized bridge monitoring solution ready for broader deployment across Central Europe.

**Activities**

The work starts by convening stakeholders through workshops to establish an expert council, review the state of the art, document owner/operator needs, define target bridge types, shortlist pilot sites, and agree letters of commitment. It then develops and tests both the digital twin approach and a cost-effective measurement system—including printed sensor foils—through transnational pilot actions, followed by multi-country implementation, comparative evaluation, and reporting.

- Stakeholder workshops, expert council setup, needs assessment, target bridge selection, pilot site list, concept video, and letters of commitment.
- Selection of BIM/digital twin methods, design of the measurement system, sensor foil specification, and pilot validation (including calibration on a research bridge).
- Implementation on bridges in Germany, Slovenia, and Italy; midterm review; comparison with existing methods; final report and stakeholder presentations.

**Phases**

**Phase 1 (WP1)** lays foundations and defines requirements via transnational engagement, a meta-study of monitoring practices, and a Central Europe strategy, during months 1–12.

**Phase 2 (WP2)** develops and pilots the digital twin and measurement system, including data sheets and whitepapers, during months 7–24.

**Phase 3 (WP3)** adapts and upscales the combined solution on pilot bridges in three countries with midterm and final evaluations, during months 19–36.

**Main outputs**

The project produces an expert council and cross-border network, a jointly developed strategy/action plan for standardized monitoring in Central Europe, and two jointly implemented pilot actions—one for the digital twin and one for the measurement system. It also delivers data sheets for sensor foils, calibration and effectiveness reports, a comparative analysis against existing methods, and midterm/final pilot reports to support uptake.

- Expert council/network of organizations and a meta-study consolidating needs, requirements, and state-of-the-art monitoring.
- Strategy and action plan for implementation and uptake across Central Europe, supported by letters of commitment.
- Pilot action validating the digital twin approach and pilot action validating the measurement system, with documentation and media assets.

  - Technical data sheet for sensor foils, whitepapers on installation/calibration, midterm review, final pilot report, and a comparative benchmarking study.
- Enabling investments (e.g., sensor-foil print station; integration with a portable weigh-in-motion platform) to support pilots and demonstrate scalability.

## 3.3. TYPE OF TECHNOLOGY

The technology part consists in two subsystems, sensors monitoring system and digital bridge representation.

**Sensors Monitoring System**

The proposed monitoring system consists of a network of sensors capable of measuring temperature, acceleration, and dynamic weight. The system is designed with a hybrid communication architecture, integrating both wired and wireless communication protocols to ensure reliable and efficient data transmission.

The sensors are interconnected through two distinct communication protocols:

*EtherCAT Communication*: A wired daisy-chain protocol used for high-speed and deterministic communication. This protocol connects the temperature sensors, dynamic weight sensors, and accelerometers, ensuring synchronized data collection and minimal latency across the measurement network.

*Wi-Fi Communication*: A wireless communication protocol employed for the leakage sensor, which is connected to a microcontroller equipped with a Wi-Fi module. This setup enables real-time wireless data transmission to the central processing unit, enhancing installation flexibility and reducing cabling requirements.

Each sensor's data is stored individually in separate '.csv' files within the Datalogger device. The Datalogger is responsible for data acquisition, local storage, and preliminary processing of each measurement. Subsequently, the recorded '.csv' files are uploaded to the Infohub Cloud server, where the control and visualization platform processes the data for analysis and monitoring purposes.

Figure 1 shows how each device connects according to the sensor monitoring system description above, illustrating the various connections from the sensors to the cloud service.

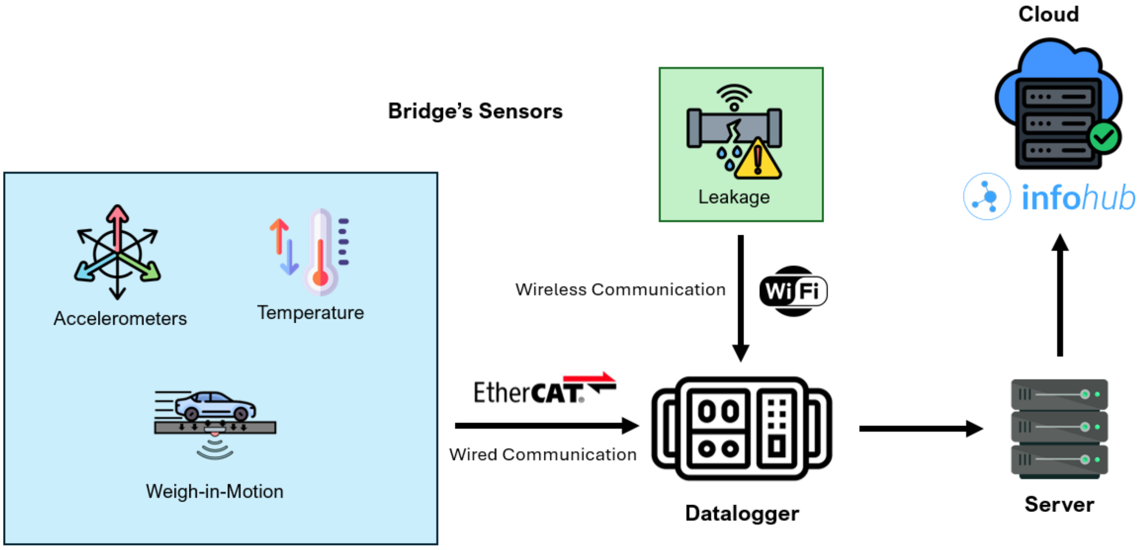


**Figure 1: Sensors Monitoring System**
**Source: Author**

**Digital Bridge Representation**

The Digital Twin concept is implemented to replicate the physical bridge structure accurately, enabling real-time observation of its behavioral and structural conditions. The bridge geometry is captured using LiDAR scanners, which acquire precise point cloud data. These data are stored in '.e57' files and later analyzed using advanced algorithms to generate a highly detailed 3D model of the bridge structure. The processed models are then converted into IFC files, ensuring interoperability with BIM systems, and subsequently uploaded to the Infohub Cloud platform for integration with the monitoring system. Figure 2 illustrates the digital bridge digitization process.

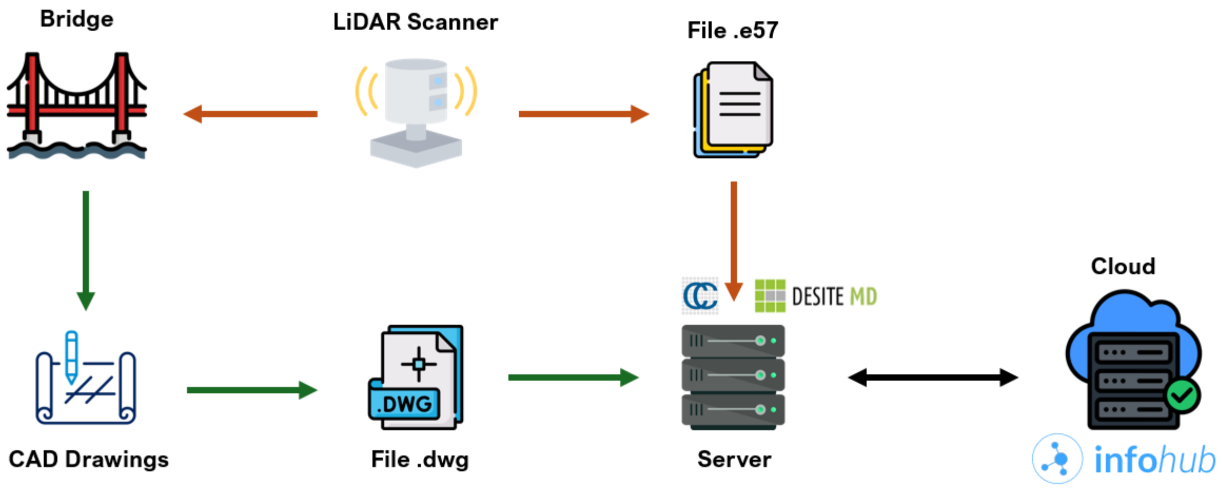


**Figure 2: Digital Bridge Representation**
**Source: Author**

The final implementation results in a comprehensive visualization, monitoring, and control platform. This platform displays: a 3D model of the bridge structure, the position and status of all sensors, and the real-time measurements associated with each monitoring point. In conclusion, the developed system provides a fully functional Digital Twin of the bridge, enabling real-time data visualization, structural health monitoring, and advanced decision support for maintenance and safety operations. In summary, figure 3 shows the final result of the project from the merger of the two subsystems.

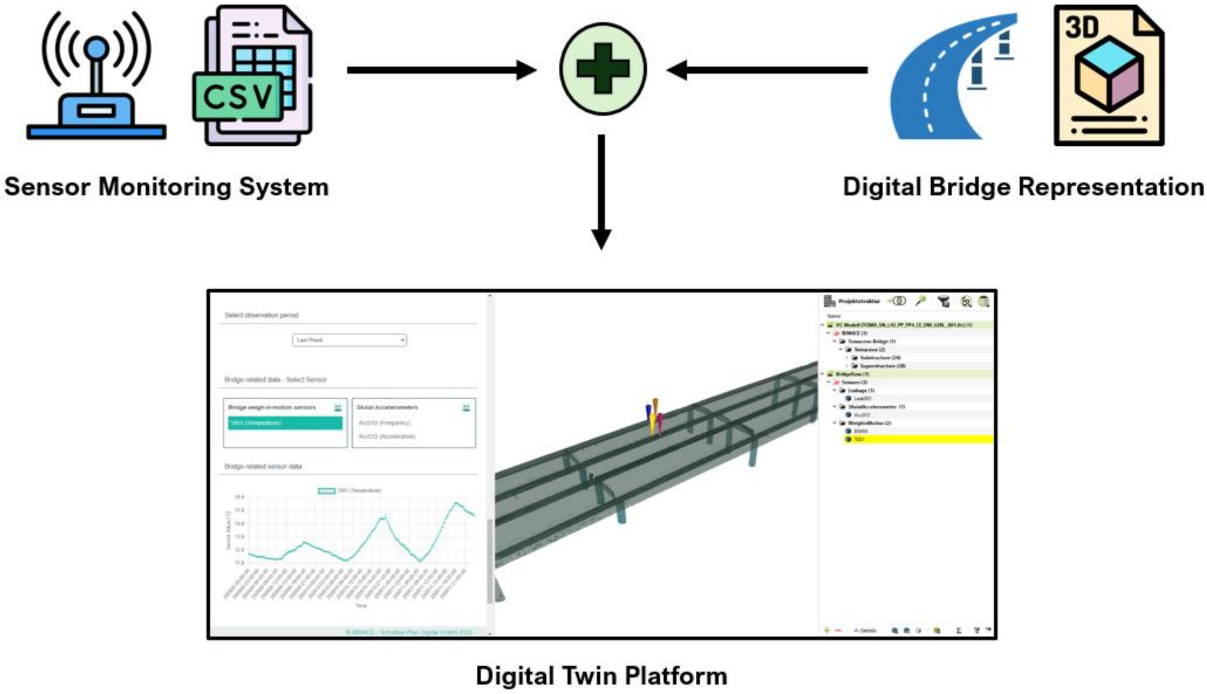


**Figure 3: Digital Twin of the Bridge with 3D Visualization and Sensors**
**Source: Author**

## 3.4. INNOVATION

The BIM4CE project introduces an innovative, integrated approach to bridge monitoring and maintenance by combining Building Information Modeling (BIM) principles with Digital Twin (DT) technology and real-time Structural Health Monitoring (SHM) systems. Its core innovation lies in merging digital construction methodologies with infrastructure management practices, fields that have traditionally operated separately.

**1. Integration of BIM and Digital Twin Technologies**

While BIM is widely used in the design and construction phases of infrastructure projects, its use in operational monitoring remains limited. BIM4CE bridges this gap by developing a BIM-based Digital Twin platform that integrates sensor data, vehicle data, and environmental conditions directly into a 3D bridge model. This integration enables continuous, data-driven monitoring of bridge performance, moving beyond static asset documentation toward dynamic lifecycle management.

**2. Affordable and Scalable SHM Solution**

Existing SHM systems are often expensive and difficult to scale for smaller municipalities or regional infrastructure owners. BIM4CE introduces a cost-effective monitoring framework using modular sensors, software tools (CloudCompare, DEWESoft X), and standardized data models. This approach lowers implementation barriers and makes continuous monitoring financially accessible, even for local authorities managing medium-sized bridge networks.

**3. Standardized Data Management and Interoperability**

The project aligns with international BIM and data standards such as ISO 19650, ensuring interoperability between software platforms and long-term traceability of all monitoring data. By structuring sensor data according to the project's Level of Information Need (LOIN) and linking it with the bridge's BIM elements through unique identifiers, BIM4CE ensures consistent data exchange across partners and systems.
The data, which is uploaded into the DT platform, is in .csv/.tsv format, which is a standard data format when dealing with large amounts of data.

**4. Integration of Structural and Traffic Data**

Unlike conventional monitoring setups that focus solely on structural parameters, BIM4CE combines structural response data (e.g., acceleration, natural frequency) with vehicle information collected from Bridge Weigh-In-Motion (WIM) systems (e.g., vehicle weight). This holistic dataset allows for a deeper understanding of load-response relationships, supporting more accurate condition assessments and predictive maintenance planning.

**5. Decision Support and Visualization**

Through the Infohub platform, all monitoring data are visualized in a user-friendly, interactive environment that supports maintenance planning and decision-making. The system enables infrastructure owners to identify anomalies, assess structural performance, and prioritize interventions based on objective, real-time evidence.

**6. Added Value for Users and Public Authorities**

For public infrastructure managers and municipalities, BIM4CE provides a practical and data-driven tool to optimize maintenance budgets, reduce inspection frequency, and extend bridge lifespan. The standardized and scalable architecture also facilitates cross-border adoption, supporting broader implementation across Central Europe.

## 3.5. SUPPLY CHAIN

**Overview**

The BIM4CE solution integrates certified sensing hardware with a secure, interoperable data platform to deliver long-term Bridge Health Monitoring (BHM) at scale. The supply chain is deliberately modular, dual-sourced where critical, and aligned with EU standards to enable cross-border deployment, fast tech-transfer to manufacturers, and supra-national certification readiness.

- Core hardware: Weight-in-Motion (WIM) sensors, accelerometers by Cestel; flexible-foil leakage sensors by TU Dresden with printed electronics; supporting electronics from tier-1 component vendors.
- Platform: Cloud integration, storage, visualization, and BIM integration delivered by SPd, using standardized data schemas to ensure interoperability and auditability.
- Governance: End-to-end documentation (BoM, supplier profiles, certificates, SOPs) structured to support technical files for CE conformity and supra-national certification submissions.

**Hardware Supplier Landscape and Sourcing Strategy**

*Tier-1 device suppliers*

- Cestel (Slovenia, EU): SiWIM bridge WIM systems, OIML R134 type-approved; XML data per COST 323; full installation, calibration, and maintenance playbooks.
- ZAG (EU research institute): Structural accelerometers; EN/ISO-aligned protocols and calibration records.
- TU Dresden: Flexible foil leakage sensors; microelectronics BoM standardized to CE/RoHS components (e.g., ESP32 modules, Microchip I/O expanders, TI op-amps; Yageo passives).

*Sourcing principles*

- Dual-source options identified for microcontrollers, passives, films, and inks to mitigate lead-time swings and obsolescence; supplier countries of origin and certificates cataloged for customs and compliance.

**Manufacturing, Installation, and Commissioning**

*Manufacturing transfer*

- Assembly notes for sensor electronics and flexible foils (substrate prep, ink curing windows, SMT/reflow constraints) standardized to enable contract manufacturing with target first-pass yield metrics in pilot runs.

*Site selection and installation*

- WIM: Structured four-step process—site selection, instrumentation, calibration, monitoring—with pre-install guardrails on geometry, roughness, and dynamics to achieve target accuracy classes (COST 323 B+(7) to A (5) on suitable bridges).

- Leakage sensors: Placement strategies for inaccessible corrosion hot-spots; retrofit-friendly flexible foils conform to curved/irregular geometries for minimal disruption.
- Accelerometers: EN/ISO-aligned vibration protocols; FFT-based signal processing and verification.

*Commissioning gates*

- Documented checklists for mechanical/electrical fit, network connectivity, data validation, and baseline capture; acceptance tests tied to quality estimators (QE) and accuracy thresholds per standard.

**Quality Assurance, Calibration, and Maintenance**

*Calibration*

- WIM: In-service calibration every six months against statically weighed trucks per COST 323/NMi procedures; quality assessment procedure for each detected vehicle.
- Leakage sensors: Laboratory calibration across temperature range 0–50 °C with max error <0.5%; on-site correction for local climate/geometry; ISO/IEC 17025 alignment and optional third-party certification pathway.
- Accelerometers: Calibration records maintained; EN/ISO vibration measurement alignment.

*Preventive maintenance*

- WIM: Semi-annual preventive maintenance during warranty; tiered service after warranty; battery and storage lifecycle plans; trained personnel requirement.
- Leakage sensors: Annual inspection of foils, adhesion verification after freeze-thaw, corrective actions, and preventive logs to ensure traceability.

*QA systems*

- Sensor QA routines, calibration records, and data integrity checks integrated with cloud dashboards; trend analysis for drift detection and SLA compliance.

**Data Pipeline, Interoperability, and Security**

*Data standards*

- SiWIM XML (COST 323) for traffic/weight data; BIM integration via IFCs; platform ingestion supporting JSON/CSV for analytics; harmonized metadata for cross-site comparability.

*Software stack and licensing*

- Open-source (CloudCompare, Python) combined with commercial tools (Desite MD; DEWESoft X bundled with hardware) to balance cost, flexibility, and robustness; license compliance tracked centrally.

*Cybersecurity and traceability*

- Role-based access control, audit trails, and standardized logs to support certification audits and chain-of-custody of measurements across borders.

**Compliance and Certification Readiness**

*Standards alignment*

- ISO 19650 (BIM information management); COST 323 and OIML R134 (WIM); CE conformity for electronics; EN/ISO vibration standards for accelerometers.

*Technical file contents*

- Supplier declarations, CE/RoHS certificates, calibration reports, installation diagrams, SOPs, and maintenance records compiled for supra-national certification submissions and customer audits.

**Sustainability and ESG**

*Lifecycle impact*

- Condition-based maintenance reduces unnecessary works, extends asset life, and lowers material and carbon intensity; quantifiable TCO and $CO_2$ reductions included in tender narratives.

*Circularity*

- Modular designs facilitate repair/reuse; material disclosures (inks, films, electronics) support green-procurement and ESG reporting requirements.

**Operations, Lead Times, and Risk Management**

*Lead-time assumptions*

- Electronics: 4-10 weeks depending on microcontrollers/passives; printed materials: 3–6 weeks; installation windows scheduled around traffic constraints; buffer stocks planned for long-lead items.

*Key risks and mitigations*

- Component shortages/obsolescence: qualified alternates and dual sourcing;
- Accuracy shortfalls: stringent site selection and calibration plans;
- Data interoperability: strict adherence to IFC/COST 323 schemas;
- Field failures: preventive maintenance schedules and swap procedures with trained staff.

# 4. ENVIRONMENTAL AND SOCIAL IMPACT OF THE PROJECT

The BIM4CE project makes a significant contribution to both environmental sustainability and social well-being in the regions involved. By combining scientific research, technological innovation, and cross-sectoral cooperation, the project fosters sustainable development and enhances public safety, while also supporting digital transformation in the infrastructure sector. Furthermore, it represents a significant step toward the digital transformation and sustainability of transport infrastructure in Central Europe. By combining innovation, environmental awareness, and social responsibility, the project delivers measurable benefits to both society and the environment. Through the development of advanced bridge monitoring systems based on digital twin technologies and real-time data acquisition, the project improves safety, reduces maintenance costs, and minimizes the ecological footprint of infrastructure management.

**Environmental Impact**

The environmental dimension of BIM4CE is centered on the principles of sustainability, prevention, and resource efficiency. The project directly contributes to the goals of the European Green Deal and the EU Strategy for Sustainable and Smart Mobility by promoting digital tools that reduce material waste, extend infrastructure lifespan, and support climate resilience.

**Reduction of Environmental Footprint**

Bridge maintenance and reconstruction traditionally require extensive use of raw materials, heavy machinery, and energy. The BIM4CE digital monitoring framework replaces frequent manual inspections and reactive maintenance with a predictive, data-driven approach, significantly reducing the environmental impact of maintenance operations.

The project’s real-time data acquisition systems allow early identification of structural deterioration, thereby avoiding large-scale repairs that consume concrete, steel, and other high-emission materials. This shift from reactive to predictive maintenance directly contributes to lowering $CO_2$ emissions and resource consumption throughout a bridge’s lifecycle.

**Sustainable Sensor Technology**

A major technological innovation developed within BIM4CE is the use of flexible, printed sensor foils created at Technische Universität Dresden (TUD). These include:

- Printable pressure sensors based on the piezoelectric or capacitive effect for measuring traffic loads;
- Printable moisture sensors that detect insulation defects and water penetration;
- Printable temperature sensors for thermal gradient monitoring of large-scale structures.

These printed sensors are produced via roll-to-roll manufacturing – an additive, low-energy process with minimal material waste and no harmful chemicals. Their polymer composition eliminates the risk of corrosion, extends service life, and reduces maintenance waste. Unlike conventional metal-based sensors, printed foils are lightweight, recyclable, and easily replaceable, which further decreases the ecological footprint.

**Reduced Energy Use and Waste**

The IoT-based monitoring architecture developed in the project enables low-energy operation and energy-efficient transmission protocols. These systems consume only a fraction of the power required by conventional monitoring setups. Moreover, many sensors are designed to operate on solar power or small rechargeable batteries, further minimizing their energy demand and environmental impact.

**Environmental Resilience and Climate Adaptation**

Climate change increases risks to infrastructure through temperature fluctuations, heavy rainfall, and freeze-thaw cycles. BIM4CE technologies, including the leakage detection sensor foils tested on pilot site in Germany, demonstrated high sensitivity to environmental parameters such as humidity, air temperature, rainfall, and solar radiation. By enabling early detection of water infiltration and condensation beneath bridge insulation layers, these sensors help prevent freeze-induced cracking, corrosion, and material degradation, reducing long-term environmental damage and resource-intensive repairs. This application supports climate adaptation by increasing the resilience of bridges against extreme weather events.

**Contribution to Sustainable Infrastructure Policy**

The BIM4CE project serves as a blueprint for sustainable infrastructure management policies. The data collected through digital twin models can inform eco-efficient asset management, helping public authorities prioritize repairs, optimize material usage, and align investment with sustainability goals.

**Social Impact**

The social impact of BIM4CE is multifaceted, encompassing safety, inclusiveness, education, and economic resilience. By combining cutting-edge technology with stakeholder engagement and capacity building, the project ensures that innovation translates into long-term social value.

**Increased Public Safety**

Bridges are critical components of national and regional transport networks. Failures can have catastrophic social and economic consequences. By providing continuous structural health information, BIM4CE helps prevent accidents, injuries, and infrastructure collapses. The project’s early-warning systems — including accelerometers, inclinometers, and moisture detection sensors — ensure that maintenance teams and local authorities receive alerts before structural degradation becomes critical.

This proactive monitoring directly enhances the safety of citizens, particularly in areas where bridges are essential for daily mobility, emergency response, and logistics.

**Promotion of Social Inclusion and Equality**

BIM4CE is committed to the principles of equal opportunities and gender equality. All partners ensure that activities — from research and training to dissemination — are accessible to both women and men, and encourage the participation of young professionals.

Project communication materials are produced in multiple languages, ensuring accessibility across Central European regions and supporting equal access to knowledge and cross-border collaboration.

**Education, Training, and Capacity Building**

A key social dimension of the project lies in outreach initiatives aimed at transferring technical knowledge to stakeholders, public authorities. etc. These programs ensure that innovation is not confined to laboratories but is embedded in regional workforce skills. Workshops and demonstration activities help local professionals acquire new competencies in digital twin technologies, IoT data analysis, and predictive infrastructure maintenance, thus strengthening employment potential in high-tech and engineering sectors.

**Economic and Community Benefits**

From an economic and social perspective, BIM4CE reduces the frequency of infrastructure disruptions, road closures, and associated economic losses. By extending the service life of bridges, public authorities save significant maintenance budgets that can be redirected to education, innovation, or community development. Furthermore, improved bridge reliability enhances regional mobility and economic integration, supporting trade and commuting patterns essential for local development.

**Citizen Awareness and Engagement**

The project also fosters public understanding of the importance of sustainable infrastructure. Through workshops and dissemination events, citizens are introduced to how digital innovation contributes to safety, sustainability, and resilience. This transparency strengthens trust between citizens, engineers, and authorities, while encouraging civic support for digital transformation initiatives.

# 5. MARKET ANALYSIS

This chapter provides an overview of the current market situation related to the project, including the main trends, market demand, and user needs.

## 5.1. MARKET ANALYSIS

**Bridge Monitoring System Market Overview**

The global market for bridge monitoring systems is experiencing robust growth, driven by aging infrastructure, increasing safety regulations, and the adoption of smart technologies. The Bridge Monitoring System (BMS) market is undergoing a transformative shift, driven by the convergence of aging infrastructure, climate resilience demands, and the rise of smart cities. Governments, private operators, and infrastructure managers are increasingly adopting advanced monitoring technologies to ensure the safety, longevity, and sustainability of bridge assets. Many bridges worldwide—especially in North America, Europe, and parts of Asia—are reaching or exceeding their design lifespans. Structural failures, like the tragic collapse of the Morandi Bridge in Genova (2018), have accelerated public and political urgency around proactive monitoring. As a result, BMS solutions are no longer seen as optional but as essential components of Modern infrastructure management.

**Main Trends**

BMS is increasingly embedded into smart city frameworks, enabling real-time data sharing across transportation, emergency response, and urban planning systems. Digital twins of bridges are being developed to simulate stress scenarios and maintenance cycles. Rapid adoption of wireless sensors over traditional wired systems due to lower installation costs, scalability, and remote accessibility Use of machine learning models to forecast structural failures and optimize maintenance schedules AI enables anomaly detection from large datasets, reducing false positives and improving safety. Drones equipped with high-resolution cameras and LiDAR are replacing manual inspections, offering faster, safer, and more accurate assessments Monitoring systems are being designed to align with eco-conscious construction, tracking carbon footprint and material degradation over time.

Table 1: Demand Drivers

| Driver | Impact |
| --- | --- |
| **Aging Infrastructure** | Bridges built 50+ years ago require continuous monitoring to prevent collapse |
| **Extreme Weather Events** | Climate change increases stress on structures, necessitating real-time diagnostics |
| **Government Regulations** | Mandates for structural health monitoring in public infrastructure projects |
| **Urbanization & Mobility Growth** | More bridges being built in expanding cities, increasing demand for scalable BMS |
| **Cost-Efficiency & ROI** | Preventive maintenance enabled by BMS reduces emergency repair costs and downtime |

**Bridge Types**

The global Bridge Monitoring System market is experiencing rapid growth, driven by the increasing need for tailored solutions across different bridge types—beam, arch, suspension, and cable-stayed. Each structure presents unique monitoring challenges, which in turn drive continuous innovation in sensors, data analytics, and ICT technologies. Industry players are actively adapting their strategies to address these diverse requirements, while collaboration between technology providers, engineers, and infrastructure owners is further enhancing safety, efficiency, and long-term asset value. This evolution highlights the growing importance of bridge-specific monitoring as a key component of modern infrastructure management.

Within this global context, a comparative analysis of bridge infrastructure in Slovenia and Germany reveals distinct structural and market characteristics that directly influence the adoption and positioning of advanced bridge monitoring systems (SHM/BWIM).

In Slovenia, the bridge network is predominantly composed of simpler structures. Slab bridges account for more than half of all bridges, followed by girder bridges, with concrete as the dominant construction material—primarily reinforced concrete, alongside a significant share of prestressed concrete. A defining feature of the Slovenian network is the high proportion of short, single-span bridges, reflecting a dispersed infrastructure designed to support local and regional connectivity. From a market perspective, this results in a large volume of relatively standardized assets, where scalable and cost-efficient monitoring solutions are particularly relevant.

At the same time, structurally more complex bridges—such as prestressed concrete girder bridges—though fewer in number, play a critical role due to their longer spans and higher operational importance. These assets represent higher-value opportunities, where more advanced monitoring and predictive maintenance solutions are required.

In contrast, the German bridge network is characterized by a higher level of structural complexity and maturity. Prestressed concrete bridges dominate, followed by reinforced concrete bridges, and the overall infrastructure is significantly older, with an average age of 50–60 years. Bridge spans are generally longer, increasing both structural demands and maintenance complexity. As a result, the German market exhibits a stronger need for advanced monitoring systems focused on lifecycle management, risk mitigation, and long-term infrastructure resilience.

Overall, this comparison highlights a clear market segmentation: Slovenia represents a volume-driven market with a high number of simpler bridges, favoring standardized and cost-effective solutions, while Germany represents a value-driven market, where aging and complex infrastructure creates demand for advanced, high-performance monitoring systems. This differentiation provides a strong foundation for targeted market strategies and solution positioning within the project.

**User Needs**

Bridge monitoring systems must respond to a diverse set of user needs across sectors. Infrastructure managers and engineers require real-time alerts to detect structural anomalies, along with remote access to sensor data and analytics dashboards. Their work also depends on seamless integration with asset management systems to support long-term lifecycle planning.

Government bodies and municipalities prioritize tools that ensure compliance with safety regulations. They seek solutions that enable budget optimization through predictive maintenance, while also reinforcing public safety and transparency in infrastructure oversight.

Construction and maintenance firms need modular systems that can be easily retrofitted onto existing bridges. Compatibility with other monitoring platforms is essential, as is access to training and technical support for deploying sensors and interpreting the data they generate.

Meanwhile, data analysts and technology providers rely on high-resolution datasets to train predictive models. They require scalable cloud-based platforms for processing and analysis, along with secure data protocols that support collaboration across multiple agencies and stakeholders.

Altogether, the market demands intelligent, interoperable, and user-centric systems that serve both operational efficiency and strategic infrastructure resilience.

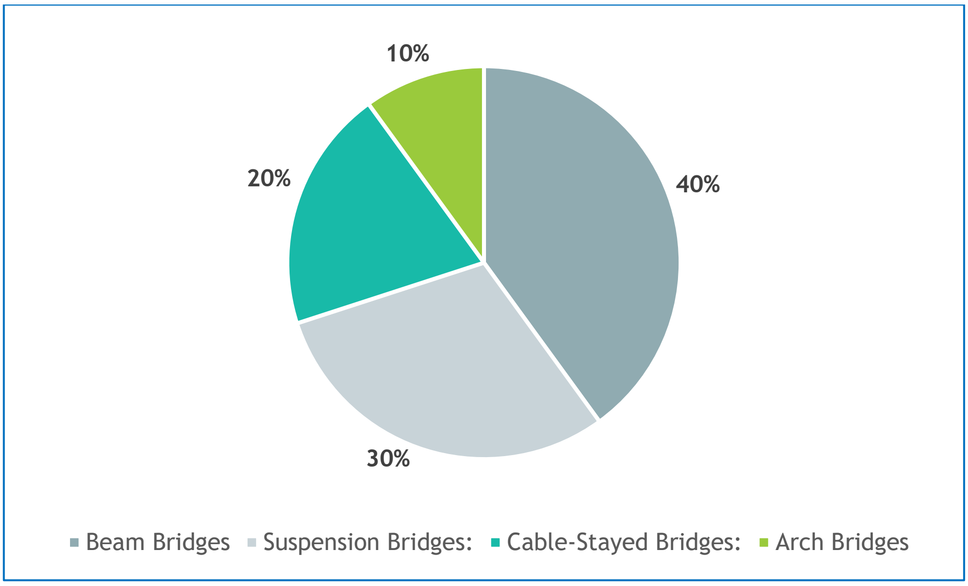


**Figure 4: Global Monitoring Bridge Monitoring System Market, by Bridge Type, 2025 (%)**[1]

## 5.2. DESCRIPTION OF THE COMPETITION

A dynamic and innovation-driven competitive environment defines the global Bridge Monitoring System market within the ICT domain. Leading companies such as IBM Corporation, Cisco Systems, and Siemens AG capitalize on their deep expertise in data analytics, IoT, and connectivity to advance monitoring technologies that ensure structural safety and integrity. These industry leaders consistently invest in R&D to deliver next-generation solutions, integrating sensors and predictive maintenance tools that set their offerings apart.

In addition, prominent players like Schneider Electric, Honeywell International, and General Electric enhance their market position through strategic alliances and collaborative efforts aimed at expanding reach and improving product capabilities. Firms such as Rockwell Automation and Emerson Electric bring their strengths in automation and control systems to deliver robust, efficient monitoring solutions.

This competitive intensity accelerates the adoption of emerging technologies and fosters continuous innovation, shaping a market landscape that emphasizes safety, efficiency, and sustainability in bridge infrastructure management.

[1] Source: Market Research Future: GLOBAL BRIDGE MONITORING SYSTEM MARKET

Table 2: Analysis of the example of the following competitor companies

| Feature / Company | Kistler | Dewesoft | Rocktech (Rockfield Technologies Australia) | BIM4CE |
|---|---|---|---|---|
| **Headquarters** | Winterthur, Switzerland | Trbovlje Slovenia [craft.co] | Townsville, Queenslans, Australia | Germany, Italy and Slovenia |
| **Core Offering** | SHM integrated with Weigh-In-Motion (WIM) systems for bridges | SHM systems for buildings, bridges, dams, wind, turbines, etc. | SHM systems with real-time analytics and visualisation for infrastructure assets | Digital Twin and BIM integrated with SHM for complex infrastructure |
| **Technology Focus** | Sensor-to-cloud platform with real-time monitoring and alerts | Distributed DAQ systems with EtherCAT, high dynamic range, and open interfaces | FEA model validation, video monitoring, and dynamic load analysis | Cloud BIM for lifecycle management |
| **Software Platform** | Cloud-based SHM&WIM software with analytics, alerts, and data storage | DewesoftX software with real-time diagnostics, math processing, and visualization | Custom visualisation platforms with anomaly alerts and performance dashboards | BIM4CE platform with interactive dashboards and IoT integration |
| **Sensor Integration** | Strain, displacement, vibration, temperature, traffic load sensors | Supports any sensor type: strain gauges, accelerometers, temperature, etc. | Integrated video, load sensors, and environmental monitoring | Compatibility with IoT sensors, BIM models, and environmental data |
| **Customization&Scalability** | Tailored solutions for each bridge; full-service support from design to operation | Modular and scalable systems for any structure; demo units available | Multi-disciplinary team designs and installs custom SHM systems | Fully scalable solutions with personalized configurations |

| Feature / Company | Kistler | Dewesoft | Rocktech (Rockfield Technologies Australia) | BIM4CE |
|---|---|---|---|---|
| **Remote Monitoring** | Yes - 24/7 cloud access and alerts | Yes - remote operation with local or cloud storage | Yes - real - time monitoring and tactical maintenance planning | Yes - remote monitoring with predictive notifications and preventive maintenance |
| **Unique Selling Point** | Combined SHM + WIM for synchronized traffic and structural data | High dynamic range and synchronization; free lifetime software updates | Integration of structural analysis with real-time monitoring and alerts | Unique integration of BIM, and SHM for asset optimization |
| **Princing Estimate** | $100,000-$500,000 USD for full system depending on bridge size and sensor count | $5,000-$150,000 USD depending on system scale and sensor types | $80,000-$500,000 AUD for full installations with maintenance plans | €50,000-€300,000 EUR depending on complexity and number of assets |
| **Installation Fees** | Inclueded in full-service package; varies by project complexity | Typically included in turnkey solutions; remote setup options available | Included in custom project scope; handled by in-house engineering team | Included in full package; on-site technical support and training |

**ADVANTAGES OF BIM4CE SOLUTION:**

**Integrated Digital Twin + BIM + SHM + WIM**

- Unlike others that focus mainly on SHM, BIM4CE combines Building Information Modeling (BIM) with Structural Health Monitoring (SHM) and Digital Twin technology, enabling full lifecycle management and predictive maintenance. The devised solution is also the only technical solution on the marker, which combines data from SHM sensors and WIM system.

**Cloud-Based BIM Platform with IoT Integration**

- While Kistler and Dewesoft offer cloud SHM platforms, BIM4CE integrates IoT sensors directly into BIM models, creating a unified environment for visualization and decision-making through Infohub.

**Scalability and Customization**

- BIM4CE offers fully scalable solutions adaptable to complex infrastructure projects, whereas competitors often provide modular or tailored SHM systems without BIM integration.

**Enhanced Remote Monitoring**

- All competitors support remote monitoring, but BIM4CE adds predictive notifications and preventive maintenance planning, improving operational efficiency.

**Unique Selling Point**

- BIM4CE's fusion of BIM, and SHM unmatched by competitors who focus on either SHM or DAQ systems.

**Competitive Pricing**

- With an estimated range of **€50,000-€300,000**, BIM4CE is positioned between Dewesoft (lower cost but limited BIM integration) and Kistler/Rocktech (higher cost for large-scale SHM).

**Portability**

All of the components of the BIM4CE system are portable and can be moved between bridges – this has a significant effect on the pricing and sustainability aspect of the solution.

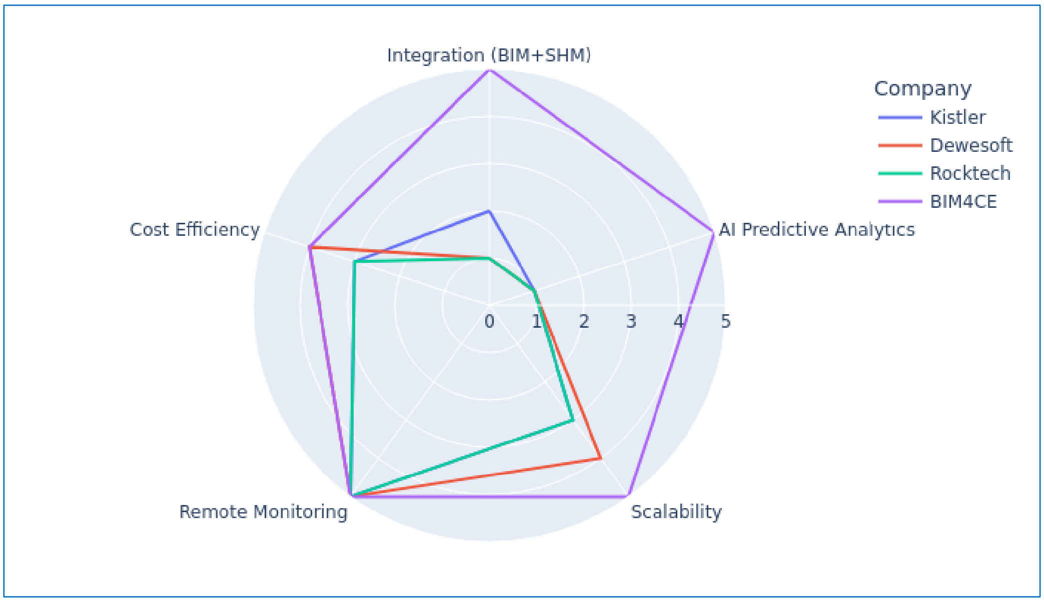


**Figure 5: Radar Chart: BIM4CE Vs Competitors**
**Source: Author**

## 5.3. MARKET ADVANTAGES AND OPPORTUNITIES OF THE PROJECT/PRODUCT

*Key advantages of the project compared to competitors and opportunities in the market, such as innovative methodologies, cross-country partnerships, new target groups.*

Project BIM4CE tackles the challenge of aging bridge infrastructure in the central European region by developing a standardized and digitized European monitoring and maintenance solution for existing bridges that is cost-effective, easy-to-use and scalable.

Existing methods for data gathering, connection and visualization were compared and evaluated in terms of cost, effectivity, effort of installation and scalability. In parallel, a new class of sensors, namely printed sensor foils based on organic electronics from TU Dresden were adapted to the technical requirements identified before.

Their advantages are flexibility, configurability (different sensors and electronics can be integrated) and very low production costs enabling large-scale application.

**Key advantages:**

- bridge/span used as a weighing platform
- installation without damage to the road (asphalt)
- sensors are not visible to the truck drivers (due to installation under the bridge)
- system can be used for various applications (traffic monitoring and analysis, bridge assessment, structural health monitoring, preselection for enforcement, etc.)
- system is portable
- low maintenance costs

**Key opportunities:**

- short term measurements (data collection at multiple locations with one system in short period of time – cost savings compared to standard road WIM)
- real time data (with use of web-based software)

**Cross-country partnerships**

Cross-border collaboration is critical for BIM4CE because the ultimate objective is to establish a standardized EU-wide digital bridge monitoring system. Engaging regions from the outset fosters acceptance and ensures success, aligning with best practices in change management. A participatory, bottom-up approach empowers communities and end-users to influence the solution, making it practical and widely adopted.

Collaboration also strengthens the solution itself: diverse stakeholders bring unique needs, ideas, and expertise that no single country can provide alone. Technical resources and experience are distributed across Germany, Slovenia, and Italy, making transnational cooperation not just advantageous but essential.

**Target Groups:**

- infrastructure providers
- Local public authority

- Regional public authority
- National public authority
- Sectorial agencies
- Enterprises operatin in the area of infrastructure monitoring

**MARKET OPPORTUNITIES**

- Untapped Potential in Emerging Markets: Developing regions are increasingly investing in infrastructure modernization, presenting significant opportunities for the deployment of bridge monitoring systems. As urbanization intensifies, governments and private stakeholders are recognizing the value of proactive structural health monitoring to prevent costly failures and ensure public safety.
- Smart City Integration Driving: Demand: The rise of smart city initiatives worldwide is fueling demand for intelligent infrastructure solutions. Bridge monitoring systems are becoming integral to these urban ecosystems, offering real-time data, remote diagnostics, and seamless integration with broader city management platforms.
- The possibility to enhance BIM4CE project with integration of AI and Machine Learning for Predictive Maintenance - The incorporation of artificial intelligence and machine learning is revolutionizing bridge monitoring by enabling predictive maintenance. These technologies analyze historical and real-time data to forecast potential structural issues, allowing for timely interventions and reducing long-term maintenance costs.

## 5.4. MARKET WEAKNESSES AND THREATS OF THE PROJECT/PRODUCT

Main weaknesses (e.g., limited duration, need for further funding, complex coordination) and external threats (e.g., slow digitalization of the sector, resistance to change, regulatory barriers).

**MARKET WEAKNESS**

- High Initial Costs: Implementing advanced monitoring systems: especially those using IoT, AI, and cloud platforms can be expensive, making adoption difficult for budget-constrained municipalities or developing regions.
- Limited Standardization: the lack of universal standards for bridge monitoring technologies and data interpretation can lead to inconsistent performance and interoperability issues across regions and vendors.
- Data Overload & Management Challenges: while real-time data is valuable, managing vast amounts of sensor data requires robust infrastructure and skilled personnel. Without proper systems, insights can be lost or misinterpreted.

- Skilled Workforce Shortage: there's a growing need for engineers and technicians trained in both civil infrastructure and digital technologies. A shortage of such hybrid skill sets can slow implementation and innovation
- Resistance to Change - Traditional infrastructure management practices may resist the adoption of new technologies, especially in regions where digital transformation is slow or met with skepticism.

**Mitigation strategies**

*High Initial Costs:*

- Public-Private Partnerships: Collaborate with private firms or technology providers for shared investment.
- Phased Implementation: Start with critical assets and expand gradually to reduce upfront costs.

*Limited Standardization:*

- Adopt Open Standards: Use internationally recognized protocols for data exchange (e.g., IFC for BIM).
- Industry Collaboration: Participate in standardization committees and alliances.

*Data Overload & Management Challenges*

- Cloud-Based Data Management: Use scalable cloud platforms for storage and processing.
- Training Programs: Equip staff with data analytics skills and provide user-friendly dashboards.

*Skilled Workforce Shortage*

- Remote Expertise: Use remote monitoring and virtual support to reduce on-site skill dependency.
- Automation: Deploy AI tools to reduce manual intervention in data interpretation.

*Resistance to Change*

- Stakeholder Engagement: Demonstrate return on investment (ROI) through pilot projects and case studies.
- Change Management Plans: Provide training and clear communication on benefits.

# 6. MARKETING STRATEGY IN CONNECTION WITH THE BIM4CE SENSORS/DIGITAL TWINS

This chapter presents the marketing strategy of the BIM4CE project for sensors and digital twins, including the definition of target markets, customer segmentation, and the assessment of business opportunities across both public and private sectors. It further outlines the geographic market entry priorities, key End-user groups, and the competitive positioning of the solution within the rapidly growing international bridge monitoring market.

## 6.1. TARGET MARKETS

The BIM4CE project targets a fragmented but rapidly consolidating market for standardized bridge monitoring solutions across Europe and beyond. The global bridge monitoring system market is valued at approximately USD 1.14 billion in 2024 and is projected to reach USD 3.69 billion by 2035, growing at a compound annual growth rate (CAGR) of 12.28%. This represents a highly attractive opportunity for a standardized, interoperable BIM-integrated platform. The primary revenue streams will be driven by hybrid service delivery models combining hardware sensors, cloud-based software platforms, and professional consulting services. Target gross profit margins for the solution are expected to range between 35-50% for software and services delivery, with hardware components typically maintaining 25-35% margins aligned with construction technology industry standards. Our segmented approach targets both public sector infrastructure authorities (B2B government) and private sector operators (B2B commercial), with specialized service packages designed to address distinct stakeholder needs across the asset lifecycle—from planning and construction to operational maintenance and end-of-service.

### 6.1.1. Market Segmentation and Opportunity Assessment

**B2B Public Sector Market (Government Infrastructure Authorities)**

The largest and most stable segment of the bridge monitoring market consists of government agencies responsible for maintaining vast networks of bridges. North America holds approximately 30% of the global market share, with Europe accounting for roughly 22.7% of market activity. These public sector entities include national highway authorities, local transportation departments, road management agencies, and dedicated bridge management offices operating at federal, regional, and municipal levels. In Europe specifically, entities such as Germany's highway authorities, France's transport infrastructure operators, and the UK's network of Local Authority bridge maintenance divisions represent key target customers. These organizations operate under regulatory frameworks demanding real-time structural health monitoring compliance, with the EU's emphasis on infrastructure safety and the European Structural Integrity and Safety Standards mandating comprehensive monitoring for critical infrastructure.

Public sector customers prioritize whole-life cost optimization, regulatory compliance, and risk mitigation.

A typical large municipality or transportation authority manages between 200 to 10,000+ bridge assets requiring continuous health assessment. The procurement model for this segment typically involves multi-year service contracts valued at €500,000 to €10 million+ depending on portfolio size, often through competitive tender processes governed by public procurement regulations.

These clients demonstrate high customer lifetime value but require extended sales cycles (12-24 months) involving multiple stakeholder groups and approval processes.

**B2B Private Sector Market (Toll Road Operators and Concessionaires)**

Private infrastructure operators and toll road concessionaires represent the second major market segment. This segment includes publicly-traded toll road companies, toll corridor operators, Build-Operate-Transfer (BOT) concessionaires, and private port and airport infrastructure operators. These entities operate within performance-based concession agreements requiring them to maintain infrastructure at specified service levels while optimizing operational costs.

Private operators face distinct commercial incentives compared to public authorities. Concession agreements typically impose strict maintenance obligations and liability frameworks, making continuous structural health monitoring economically compelling as a cost-avoidance measure. Preventive maintenance strategies enabled by real-time monitoring can reduce whole-life costs by 7-10% compared to reactive approaches. The private sector segment represents approximately 40-45% of the monitored bridge infrastructure in developed European markets, with growth concentrated in emerging European markets and Asia-Pacific regions where PPP infrastructure models dominate. These customers demonstrate shorter sales cycles (6-12 months) and higher willingness to adopt integrated digital solutions, often bundling monitoring services with broader asset management platforms.

### 6.1.2. End Customer Segments and Main User Groups

The bridge monitoring market comprises four core customer segments that combine purchasing authority, operational usage, and regulatory influence:

1. **Public Infrastructure Owners and Transportation Authorities**
   Public agencies and regional transportation authority's responsible for managing large bridge portfolios across multiple jurisdictions. This segment controls capital and operating budgets and acts as the primary procurement authority. Key priorities include public safety, regulatory compliance, political accountability, and long-term asset lifecycle performance. Purchasing criteria focus on total cost of ownership, multi-year return on investment, standardized reporting compliant with national and EU regulations, minimal operational disruption, and proven deployments with comparable public agencies.
2. **Private Toll Road and Concession Operators**
   Private infrastructure owners and operators managing revenue-generating bridge assets under long-term concession agreements. This segment acts as both asset owner and commercial decision-maker.

Core priorities include revenue protection, concession performance compliance, liability mitigation, and shareholder value. Buying criteria emphasize quantified risk reduction, seamless integration with enterprise IT and ERP systems, dynamic maintenance scheduling to minimize traffic disruption, competitive performance differentiation, and robust reporting to concession authorities over multi-year concession periods.

3. **Engineering, Maintenance, and Operations Organizations**
   Public and private engineering departments and maintenance service providers responsible for daily inspections, diagnostics, and maintenance execution. This segment represents the primary operational users of monitoring systems. Key priorities include early fault detection, reduced manual inspection workload, efficient maintenance planning, and data-driven decision making. Solution requirements include actionable analytics, real-time alerts, integration with existing inspection and maintenance workflows, mobile access for field teams, intuitive dashboards, and rapid user onboarding with minimal training burden.
4. **Traffic Management, Emergency Operations, and IT Governance Authorities**
   Centralized traffic management and emergency response centers, together with public-sector and enterprise IT organizations overseeing system security, data governance, and platform integration. This segment influences system selection through operational readiness and digital compliance requirements. Core priorities include standardized alerting and escalation protocols, multi-site command-and-control capability, high system availability, cybersecurity and data sovereignty compliance, open APIs for integration, role-based access control, and documented disaster recovery and business continuity processes. Regulatory and oversight authorities within this segment further drive adoption through monitoring mandates, certification frameworks, and compliance reporting requirements.

### 6.1.3. Geographic Market Prioritization

The market entry strategy prioritises regions with high infrastructure monitoring demand, strong regulatory readiness, and reference potential, leveraging existing pilot sites in **Germany, Italy, and Slovenia** as anchor markets. Initial expansion focuses on **Central Europe** before scaling across broader European regions and selected global markets.

**Phase 1 (Months 1-18): Central Europe Core Market + Adjacent Western Europe**
**Primary focus: Central Europe**, anchored by existing pilots in **Germany and Slovenia**, with early commercial traction built around reference deployments.
**Target markets:** Germany, Austria, Switzerland, Czech Republic, Poland, Italy.
This phase prioritises regions with:

- Mature bridge infrastructure portfolios (average bridge age 40+ years)
- Strong regulatory and safety frameworks supporting standardized monitoring
- High public infrastructure budgets and established procurement procedures

- Existing BIM adoption in infrastructure planning (15–25% penetration)
- Availability of pilot references in Germany and Slovenia to accelerate procurement cycles

Target addressable market: €180–250 million annually

Strategic objective: Establish category leadership in Central Europe, convert pilot sites into long-term reference customers, and secure flagship public-sector deployments in core EU infrastructure markets.

**Phase 2 (Months 19–36): Southern and Nordic Europe Expansion**

**Target markets:**

Spain, Portugal, and Nordic countries

This phase builds directly on existing pilot validation in Italy and Slovenia, expanding into regions characterized by:

- Accelerated infrastructure modernization and rehabilitation programs
- Rapid growth in PPP and concession-based infrastructure ownership
- Emerging regulatory frameworks mandating continuous or standardized monitoring
- Increasing digitalization of asset management and inspection workflows

Target addressable market: €120–180 million annually

Strategic objective: Scale across Southern and Northern Europe by leveraging proven Central European references and early pilot success in Italy, with a strong focus on concession operators and national highway authorities.

**Phase 3 (Months 37+): Selective Global Expansion via Strategic Partnerships**

**Target regions:**

North America and Asia-Pacific

Market entry is pursued selectively through regional partners, targeting:

- Toll road operators managing major long-term concessions
- National highway authorities with centralized procurement and large bridge portfolios
- Markets with high infrastructure replacement and resilience investment programs

Target addressable market: €250–400 million annually

Strategic objective: Enter high-value international markets through partnerships, replicating the European reference model and focusing on large-scale concession and national authority deployments.

### 6.1.4. Competitive Positioning and Market Entry Strategy

The BIM4CE solution will differentiate from existing point solutions (sensor manufacturers, software platforms, consulting firms) through integrated standardization, interoperability compliance, and BIM-native architecture. Current market leaders (Kistler, Honeywell, Digitex Systems) typically offer either hardware-centric or software-centric solutions with limited BIM integration. Our horizontal integration strategy offers:

- Open-architecture design compatible with third-party sensors and existing infrastructure investments
- BIM-native data models enabling design-to-operations workflow continuity
- Standardized data exchange formats (COBie, IFC, MiniSEED) reducing customer lock-in and supporting data migration
- Modular pricing enabling customers to adopt incrementally without forklift system replacement

This positioning targets the 90% of infrastructure operators currently using fragmented, non-integrated solutions and facing increasing regulatory pressure to standardize data management approaches. The addressable serviceable obtainable market (SOM) for BIM4CE in target geographies is estimated at €40-80 million annually within a 5-year timeframe, representing 8-15% market penetration based on reasonable competitive positioning and sales execution assumptionsmptions.

## 6.2. MARKETING CHANNELS AND MARKET COMMUNICATION

How the results will be communicated and disseminated.

We plan to develop commercial partnerships with engaged key partners in each target country. Our strategy is to cooperate with strategic sales and distribution partners in the target countries and sign specific agreements and/o r licensing agreements. We also plan to increase marketing activities to enhance customer engagement (B2B meetings, Web and Social campaigns, participation in events). We will individuate potential customers to engage and we will develop a marketing strategy to address every customer with the most appropriate promotion approach.

Our scope is to develop a social media promotion through the main social networks and promote customer engagement among stakeholders of the industry.

We will reach our potential customers through direct contacts (telephone and e-mail channels), as well as through the participation to B2B meetings, workshops, conferences and fairs.

**Table 3: Marketing and Commercialization Strategy Overview**

| | DESCRIPTION |
|---|---|
| **Product** | Digital twin platform for the bridge monitoring using sensing system and digital 3D representation. |
| **Price** | (See table 4) |
| **Distribution** | The distribution channel considering the type of product and the type of customers will be through direct sales. Distribution and marketing will be conducted in international target countries. Commercial agreements will be established with engaged key partners. |
| **Promotion** | A promotion channel towards buyers will be the publication in specialized scientific journals, as well as the presentation of results at conferences focused on bridge monitoring.<br>The promotion will also be entrusted to a dedicated website that will illustrate the potential of the BIM4CE solution for the specific applications of these markets.<br>Other promotional activities include direct contact with the CIOs (Chief Information Officers) of potential customers, organization of “web and social" promotion campaigns, participation to B2B meetings, workshops, conferences and fairs in the field of bridge monitoring. |

In addition, a social media promotion will be conducted, targeting both consumers and corporate networks (e.g. Facebook, LinkedIn, YouTube). This will allow the characteristics and added value of BIM4CE solution to be widely disseminated among industry experts and stakeholders.
Furthermore, it will disseminate the solution and offer in the most relevant events related to Bridge Monitoring, as well as the participation in technical meetings focused on these topics (for example, conferences, workshops and seminars).

**Table *4*: System specifications and price range**

| | BWIM | Accelerometers | Leakage sensors | Software | Price estimation |
|---|---|---|---|---|---|
| **Tier 1<br>2-lanes<br>Single span bridge** | 12-ch BWIM system | 6 accelerometers | 2 leakage sensors | Infohub | Between 80.000 EUR and 100.000 EUR |
| **Tier 2<br>4-lanes<br>single span monitoring** | 24-ch BWIM system | 12 accelerometers | 4 leakage sensors | Infohub | Between 100.000 EUR and 140.000 EUR |
| **Tier 3<br>4 lanes or more<br>Multi span monitoring** | 32-ch BWIM system or 2x 32-ch BWIM system | As required | As required | Infohub | From 140.000 EUR on |

**Table 4** presents rough price estimations of the system developed during the BIM4CE project. The factors, that have the largest impact on the price are the following:

- Dimensions of the bridge
- Number of sensors
- Number of traffic lanes
- The complexity level of the 3d model

The table thus serves as a rough guide on the prices; exact prices would be determined on a project basis.

## 6.3. FINANCIAL RESOURCES FOR THE MARKETING STRATEGY

The project budget foresees financial resources for dissemination and communication activities. Around 50.000 €/year would be useful for the period After the project to be allocated to the marketing strategy Analysis & Strategic Planning, Branding & Promotional Materials, Digital Marketing (SEO, Social, PPC), Content Marketing (blogs, videos, graphics), Events & Public Relations, Tools & Software and Monitoring & Reporting are some examples where these resources should be allocated.
Financial resourses will come from:

**1. Internal Financing**

Allocate a percentage of revenue: Typically, 5-10% of annual revenue for marketing.
Reallocate existing budgets: Shift funds from low-performing activities to marketing.
Cost optimization: Reduce operational inefficiencies to free up resources.

**2. External Funding Sources**

EU Grants & Programs:

- Interreg, Horizon Europe, LIFE, COSME often cover communication and dissemination costs.
- National or Regional Grants:
- Many countries offer co-financing for EU projects or SME marketing initiatives.
- Private Partnerships & Sponsorships:
- Collaborate with industry partners for co-branding or joint campaigns
- Bank Loans or Credit Lines

# 7. EXPLANATIONS TO THE FINANCIAL APPENDIX OF THE BUSINESS PLAN

This chapter provides a detailed explanation of the Financial Appendix of the Business Plan, outlining the structured service offerings, the integrated revenue model (hardware, software, and professional services), and the projected margin framework that underpins the long-term financial sustainability and competitive positioning of the BIM4CE solution in the infrastructure technology market.

## 7.1. SERVICE OFFERINGS AND PRODUCT PORTFOLIO

### 7.1.1. Tiered Service Packages

The BIM4CE project will deliver a three-tier service model designed to segment customers by portfolio size, technical sophistication, and budget constraints:

*Tier 1: Essential Monitoring Package (€50,000 - €300,000 annual subscription) Designed for regional authorities and smaller private operators managing 20-100 bridges. This package includes:*

- Installation of basic sensor networks (accelerometers, tiltmeters, environmental sensors) on critical spans
- Cloud-based data aggregation and storage with 3-year data retention
- Monthly standardized PDF reports highlighting structural status in "traffic light" format (green/yellow/red)
- Email and SMS alert notifications for threshold exceedances
- Basic mobile application for field inspection coordination
- Expected gross margin: 45-50% driven by SaaS subscription model with minimal customization

*Tier 2: Advanced Analytics Package (€300,000 - €2,000,000 annual subscription) Positioned for large transportation authorities and premium toll operators managing 100-500 bridge assets. Enhanced capabilities include:*

- Comprehensive multi-parameter sensor networks with wireless LoRaWAN integration
- Advanced analytics including Operational Modal Analysis (OMA), damage detection, and modal frequency tracking
- Integration with BIM models for design-condition versus in-service performance comparison
- Customizable dashboards with predictive maintenance algorithms and remaining useful life (RUL) estimation
- Real-time API integrations with customer asset management and enterprise resource planning (ERP) systems
- Quarterly strategic consulting and optimization reviews with certified bridge engineers

- Expected gross margin: 40-45% reflecting increased consulting time allocation and infrastructure costs

*Tier 3: Enterprise Integration Package (€2,000,000 - €15,000,000+ multi-year contracts) Reserved for national-scale infrastructure networks and multinational toll operators. Comprehensive offerings include:*

- Full-stack deployment across 500+ bridge portfolio with custom sensor selection and deployment strategy
- White-labeled software platform with dedicated cloud infrastructure and data sovereignty compliance
- Direct integration with transportation management systems, inventory databases, and financial systems
- Dedicated onsite technical team (2-4 full-time engineers) for operations support
- Annual strategic asset optimization consulting worth €500,000+
- Expected gross margin: 35-40% reflecting significant implementation costs and personnel allocation

## 7.2. COMBINED REVENUE MODEL: HARDWARE, SOFTWARE, AND SERVICES

The economic model integrates three complementary revenue streams:

*Hardware Sales (25-40% of total revenue)*

- Sensor units: €800-€3,500 per unit depending on complexity, with average deployment of 8-15 sensors per bridge = €6,400-€52,500 per asset
- Installation and cabling: €5,000-€25,000 per bridge site
- Wireless communication gateways and edge computing devices: €3,000-€8,000 per installation
- One-time hardware margin: 25-35%
- Hardware refresh cycles: 7-10 years enabling recurring replacement revenue

*Software Licensing and Cloud Services (40-50% of total revenue)*

- Annual SaaS subscription fees: €2,500-€50,000 per bridge asset depending on analytics tier
- Data storage and computing infrastructure costs: €50-€300 per asset annually, supporting 35-40% software margins
- Premium reporting and custom dashboard features: €10,000-€100,000 per customer annually
- Software-as-a-Service margin: 45-50%, leveraging cloud economics and minimal marginal customer acquisition costs

*Professional Services and Consulting (10-20% of total revenue)*

- Installation and commissioning services: €2,000-€8,000 per bridge
- Staff training and certification: €5,000-€50,000 per customer organization

- Data interpretation consulting and remediation strategy development: €50,000-€500,000 annually for Tier 2-3 customers
- Custom integration and system optimization: €10,000-€200,000 per engagement
- Professional services gross margin: 50-65% driven by high-value knowledge-based work

## 7.3. MARGIN STRUCTURE AND COMPETITIVE POSITIONING

The composite gross margin target for the BIM4CE solution portfolio is 38-42% across all revenue streams, positioning the offering competitively within infrastructure technology markets.

**Table 5: Margin Structure by Revenue Stream**

| REVENUE STREAM | MIX PROPORTION | UNIT MARGIN | WEIGHTED CONTRIBUTION |
|---|---|---|---|
| **Hardware Sales** | 30 % | 30 % | 9 % |
| **Software/SaaS** | 45 % | 47 % | 21 % |
| **Professional Services** | 25 % | 55 % | 14 % |
| **Total Blended Gross Margin** | 100 % | / | 44 % |

This margin profile enables sustainable investment in R&D (12-15% of revenue), sales and marketing (18-22% of revenue), and technical support infrastructure (8-10% of revenue) while delivering 8-12% net operating margins typical of high-growth software and infrastructure technology companies. The margin structure aligns with international construction services benchmarks where gross margins range from 15-25% for hardware-heavy projects and 40-60% for consulting-dominant engagements.

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# 8. APPENDICES OF THE BUSINESS PLAN

- Broshure
- Poster

Interreg CENTRAL EUROPE
Co-funded by the European Union
BIM4CE

## BIM4CE - BRIDGE MONITORING USING REAL-TIME DATA AND DIGITAL TWINS FOR CENTRAL EUROPE

Bridges are critical infrastructure in many ways. However, the maintenance of these assets is often complicated and expensive. BIM4CE will design a more generalized digital solution for bridge management that is effective enough to help its operators with maintenance decisions yet not too complex or cost-intensive.

The goal is offer a bridge monitoring solution that is digital, affordable and scalable, benefiting all Countries and Citizens in the European Union.
Starting from bridges in central Europe, in the future other important buildings will be equipped with similar smart systems for equal reasons.

**This project is supported by the Interreg CENTRAL EUROPE Programme with co-financing from the European Regional Development Fund.**

Interreg CENTRAL EUROPE
Co-funded by the European Union

**PROJECT BUDGET**

**2,70 m €**

**DURATION**

Start Date **04.2023**

End Date **03.2026**

The team active on the BIM4CE Project is composed of experts in the Construction of Bridges, IoT and Digital Twin.

**8** PARTNERS

**3** COUNTRIES

## GERMANY

**Technische Universität Dresden**
Dresden
Lead Partner | Collaboration in the design of innovative technological sensors for bridge monitoring solutions.

**Schüßler-Plan Digital GmbH**
Düsseldorf
Design and creation of BIM-based Digital twins for bridges.

## ITALY

**FOS S.p.A.**
Genoa
Co-leader of the project and coordinator of social media communication and management.

**CSP ICT Innovation**
Turin
Design and realization of IoT architectures and communication infrastructure between sensors, data analysis and visualization.

**SINA**
Milan
Participation in the investigation of state-of-the-art monitoring systems in the Central European region.

## SLOVENIA

**BP Akademija**
Murska Sobota
Research activities for data analysis and preparation results in the form of stakeholder maps, reports, presentations and whitepapers.

**Cestel**
Trzin
Measurement system design by providing strain gauge sensors and other data collection tools. Software development with feedback and consultation.

**ZAG Slovenje**
Ljubljana
Allow access to data on Slovenian road and bridge infrastructure; testing and comparative analysis of different sensor types.

Contact
Technische Universität Dresden
Professor Karl Leo | karl.leo@tu-dresden.de
Clemens Haist | clemens.haist@tu dresden.de

Interreg CENTRAL EUROPE
Co-funded by the European Union
BIM4CE

**Bridge monitoring using real-time data and digital twins for Central Europe.**

Bridges are critical infrastructure in many ways. However, the maintenance of these assets is often complicated and cost-intensive.

BIM4CE will design a more generalized digital solution for bridge management that is effective enough to help its operators with maintenance decisions yet not too complex or cost-intensive.

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| | |
|---|---|
| 2,701,235.41 | Project budget in EUR |
| 2,160,988.32 | ERDF funding in EUR |
| 01.04.2023-31.03.2026 | Project duration |

www.interreg-central.eu/projects/bim4ce/

**Contact**
Technische Universität Dresden
Professor Karl Leo | karl.leo@tu-dresden.de
Clemens Haist | clemens.haist@tu-dresden.de